



Australian Government

Australian Transport Safety Bureau

Tiger Moth in-flight break-up investigation

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AVIATION | MARINE | RAIL

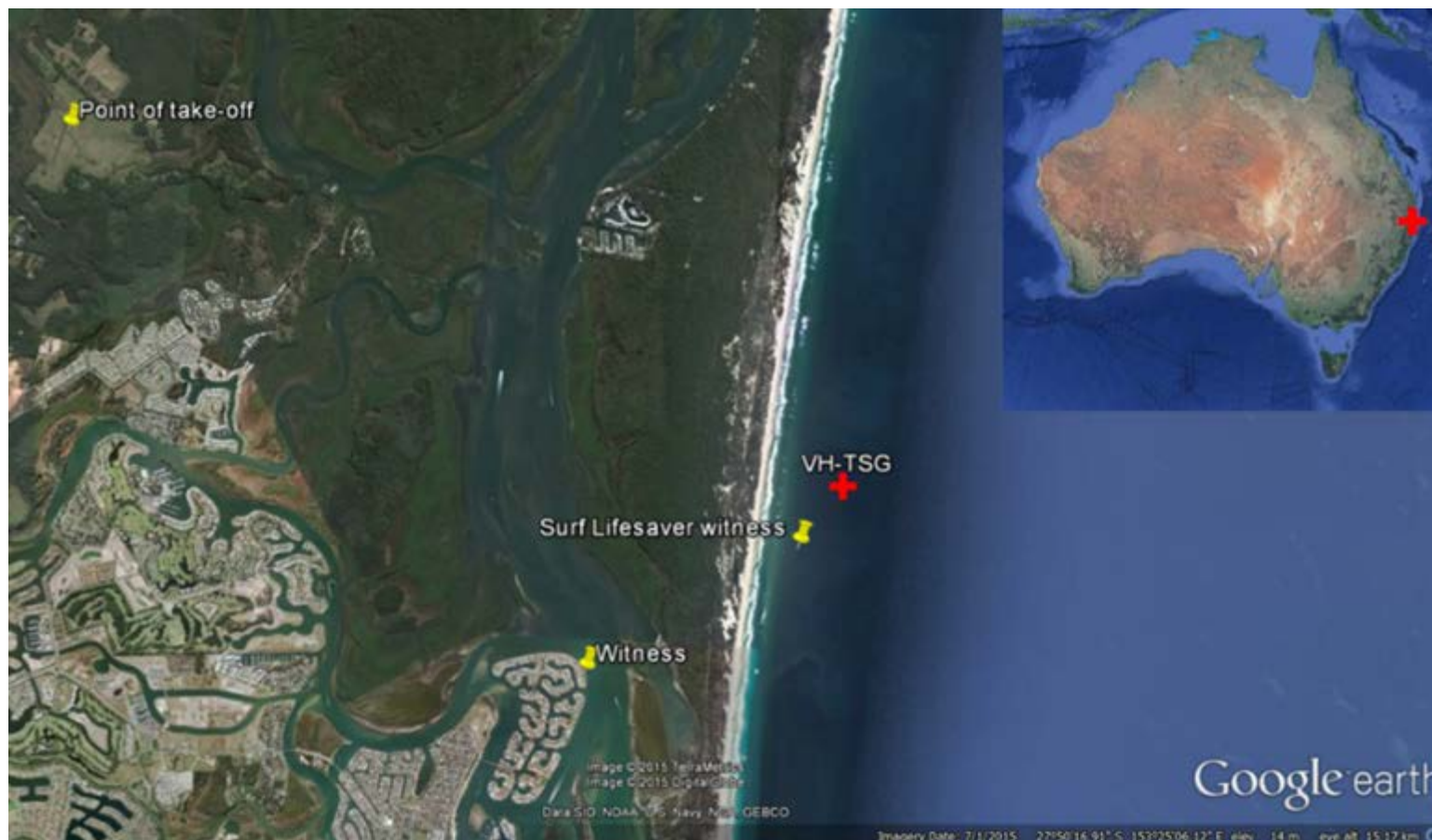
www.atsb.gov.au

Discussion points

- The occurrence
- On-site investigation
- Explanation of the aircraft's wing structure components
- In-flight break up mechanism
- Commercial operations with high aerobatic usage
- Parts manufacturing approvals
- Safety issues and actions
- Questions...

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Aircraft location



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On-site investigation

Flotsam



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On-site investigation

Aircraft recovery



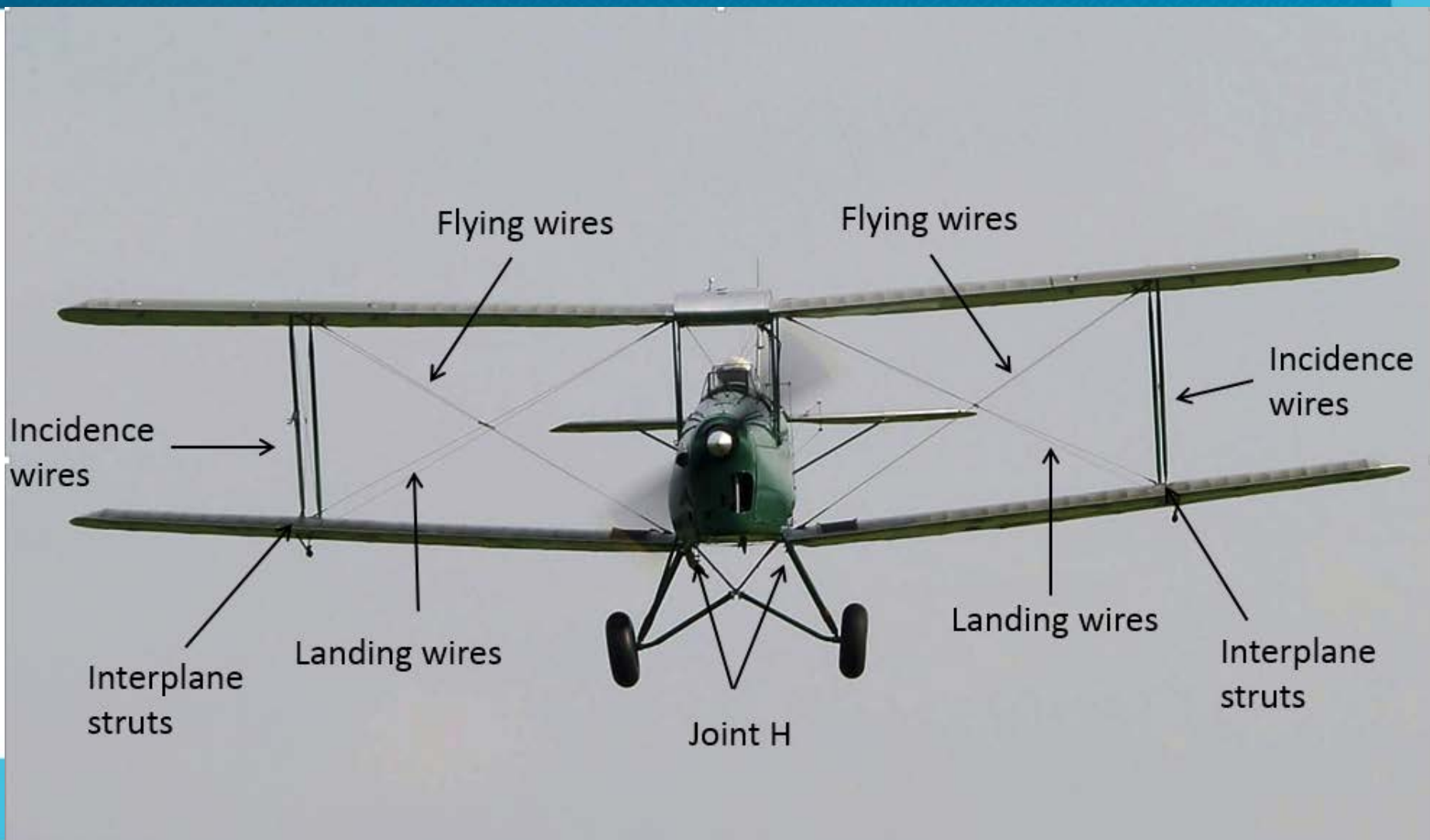
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Aircraft wreckage

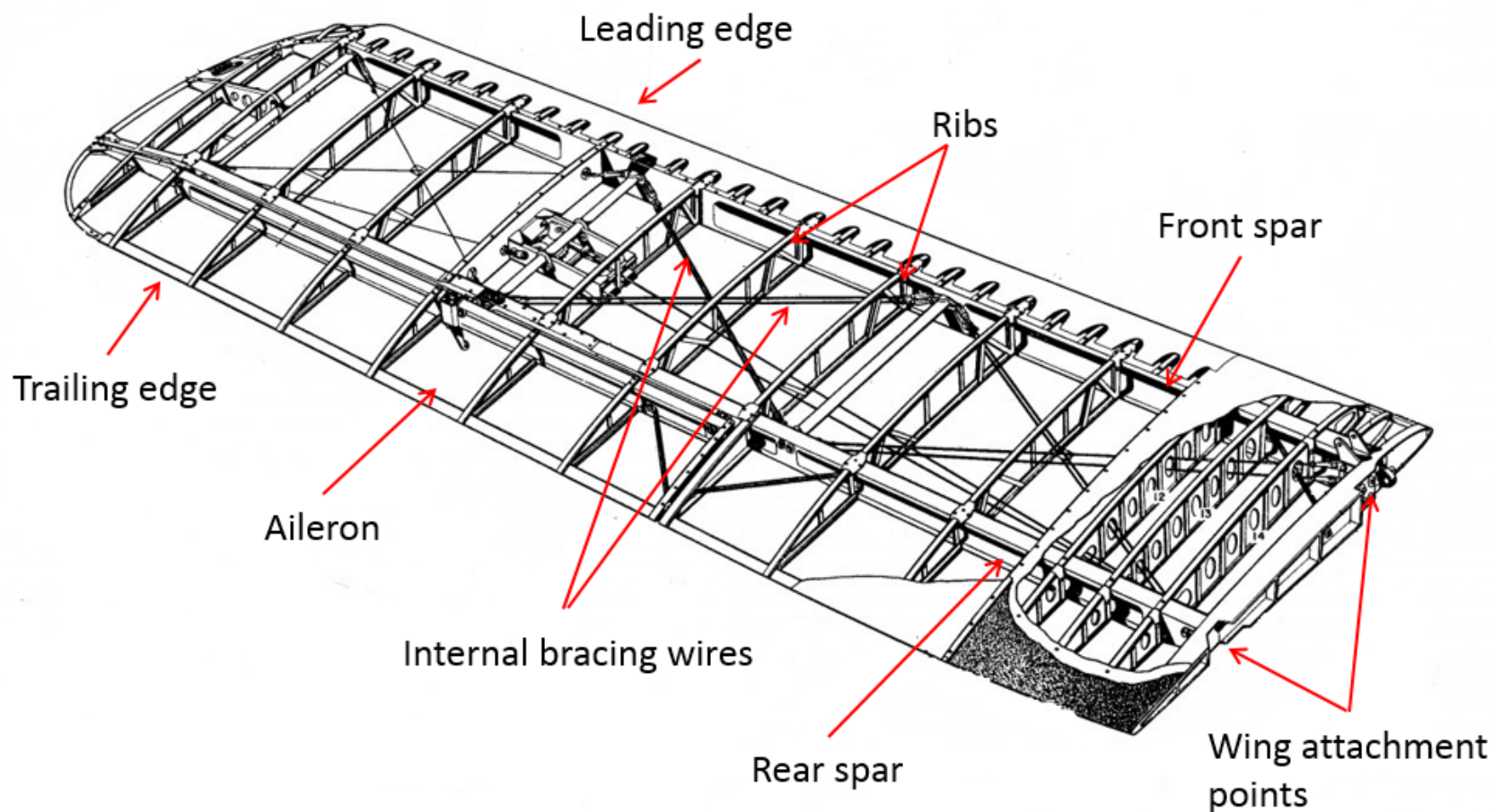


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Aircraft structure

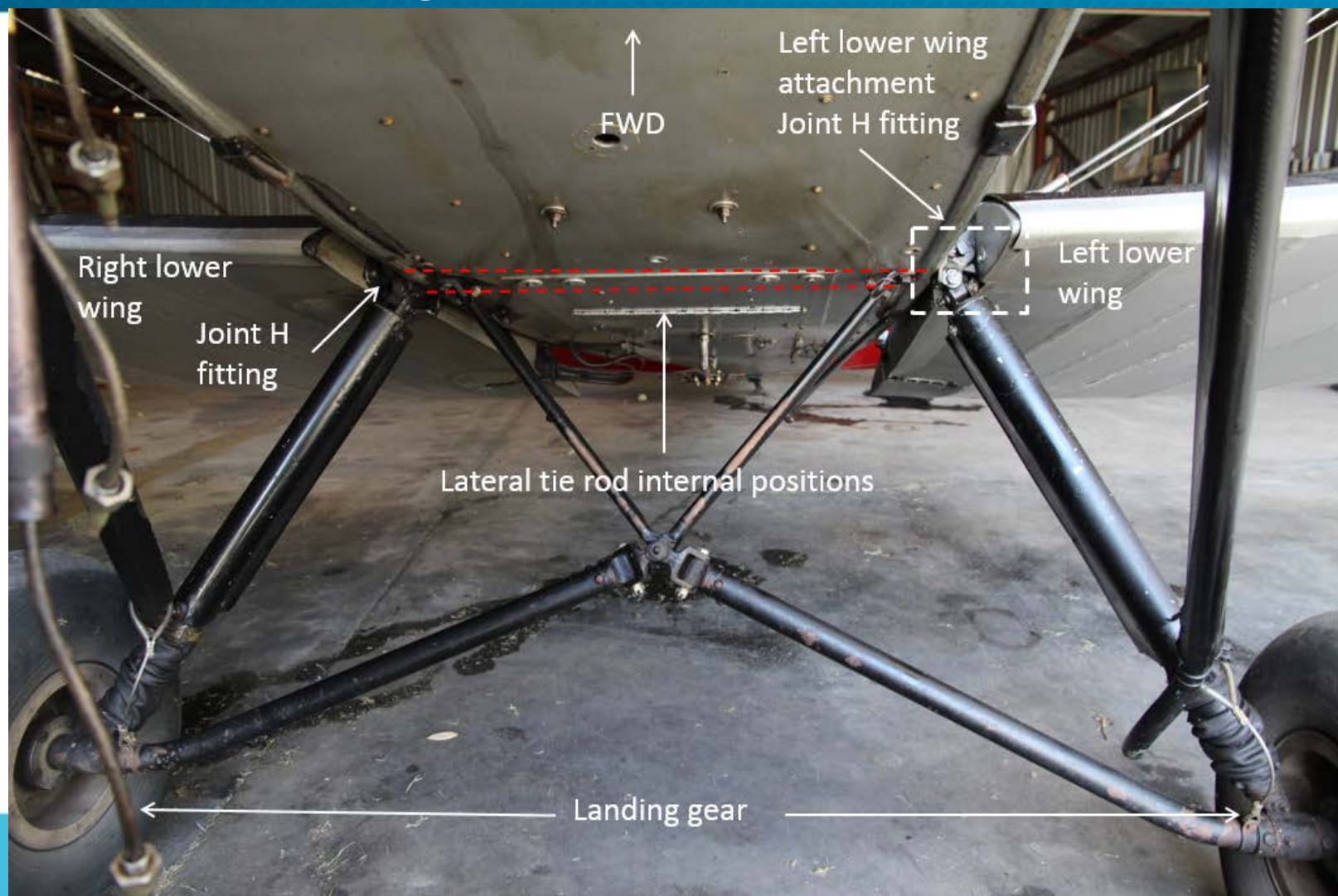


Wing structure

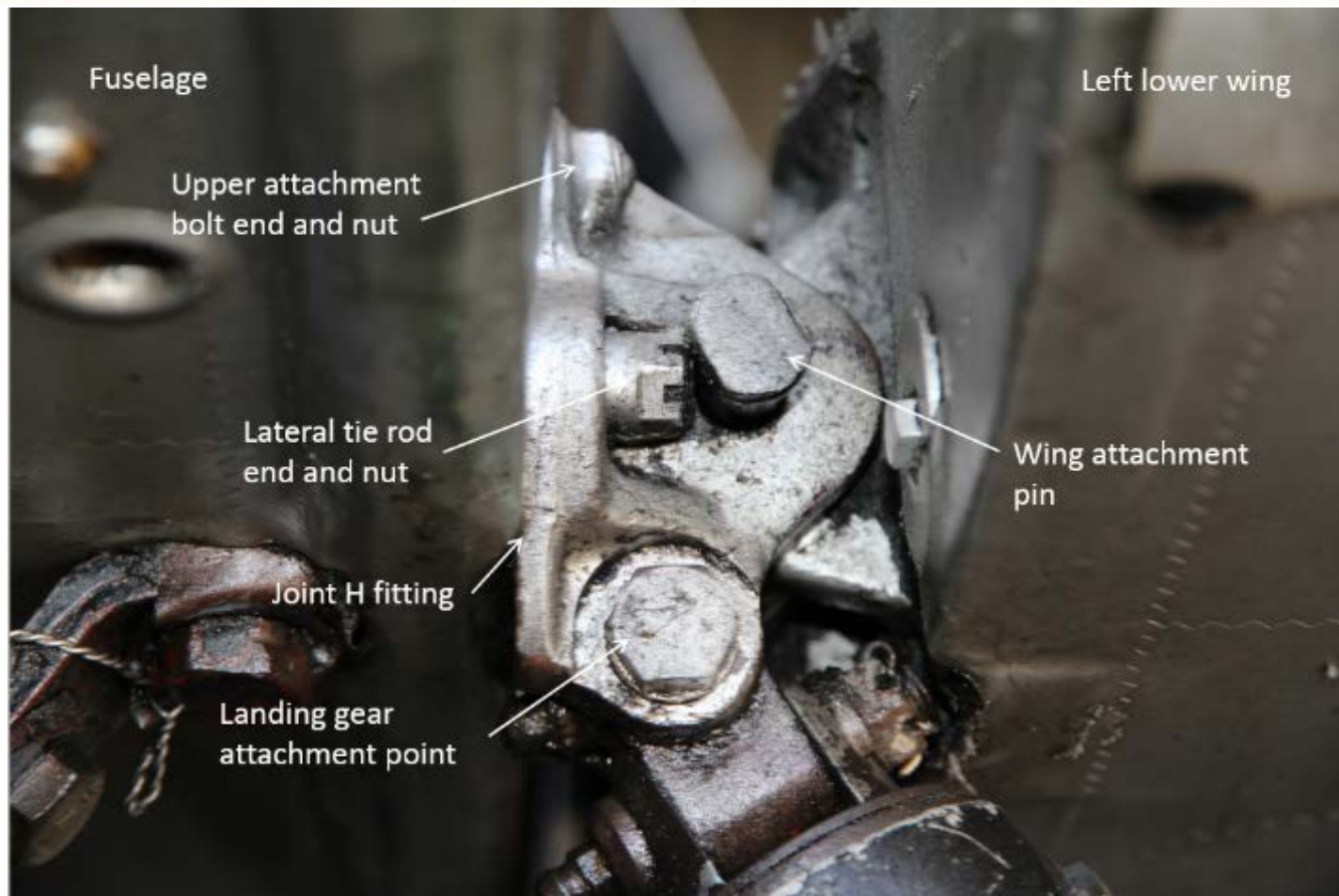


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Lower wing attachment

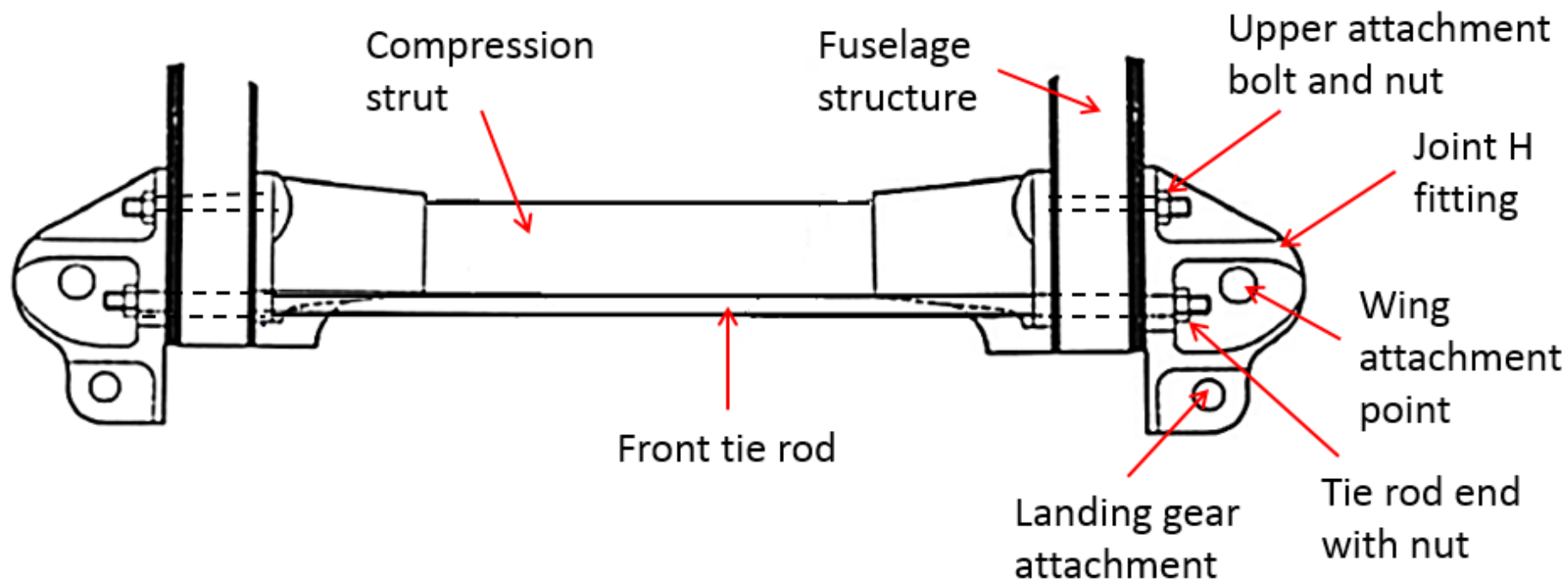


Joint H fitting



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Fuselage structure at Joint H



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Wreckage reassembly



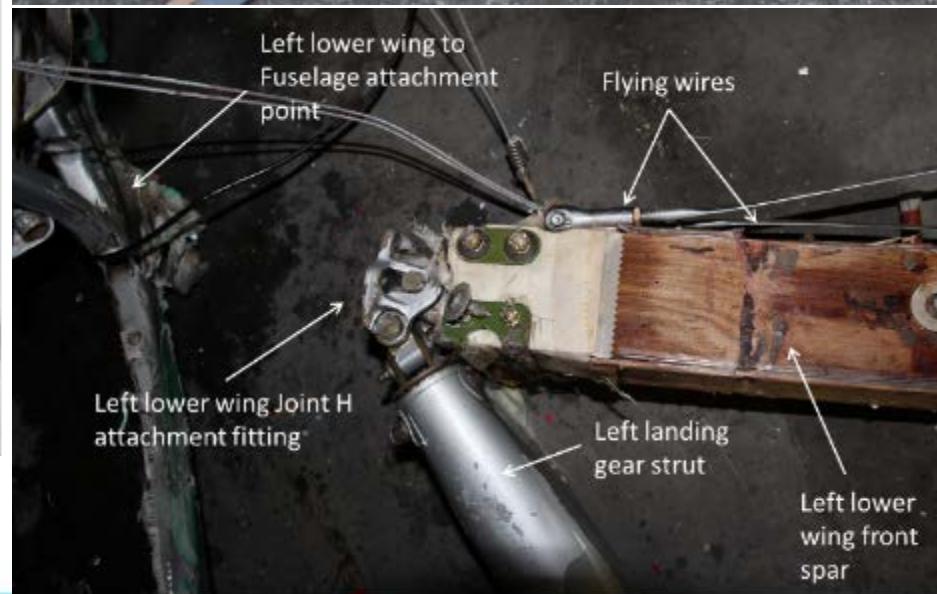
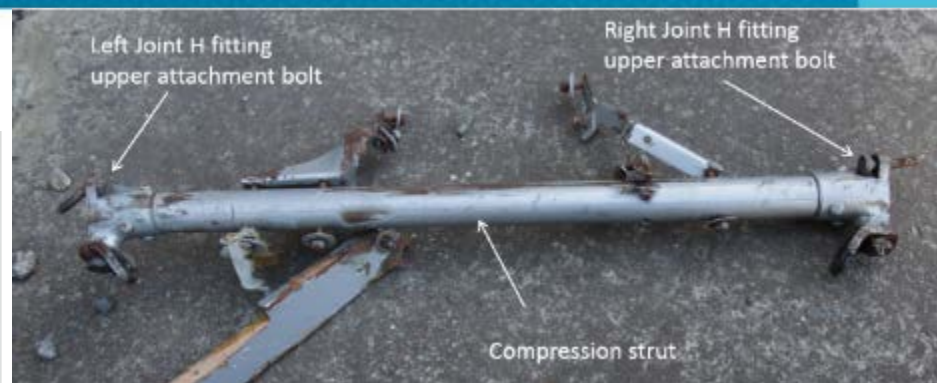
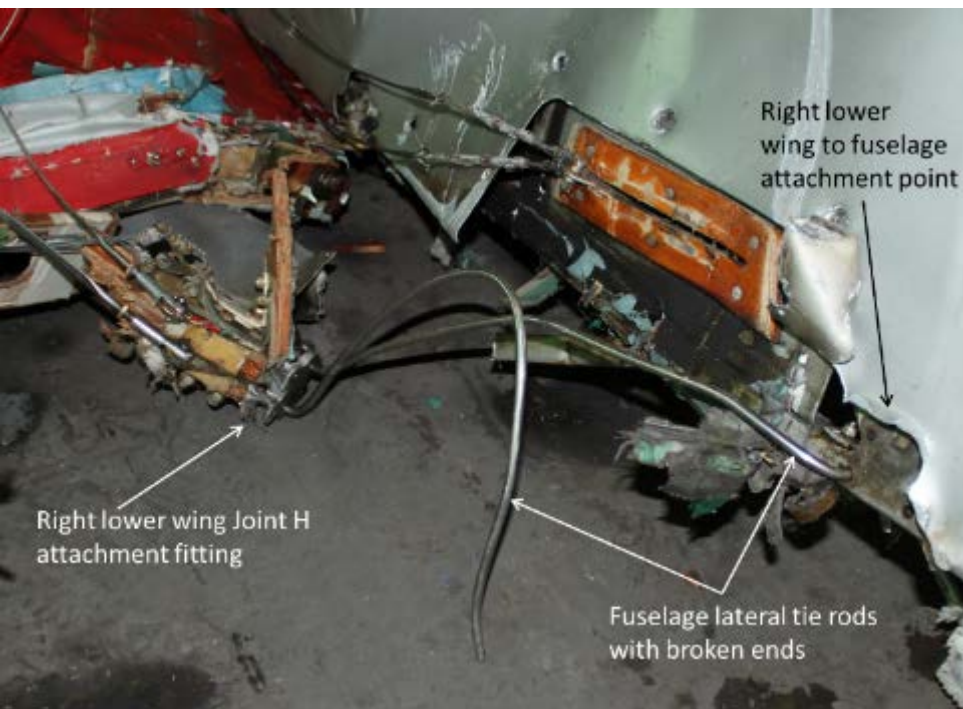
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Left lower wing reassembly



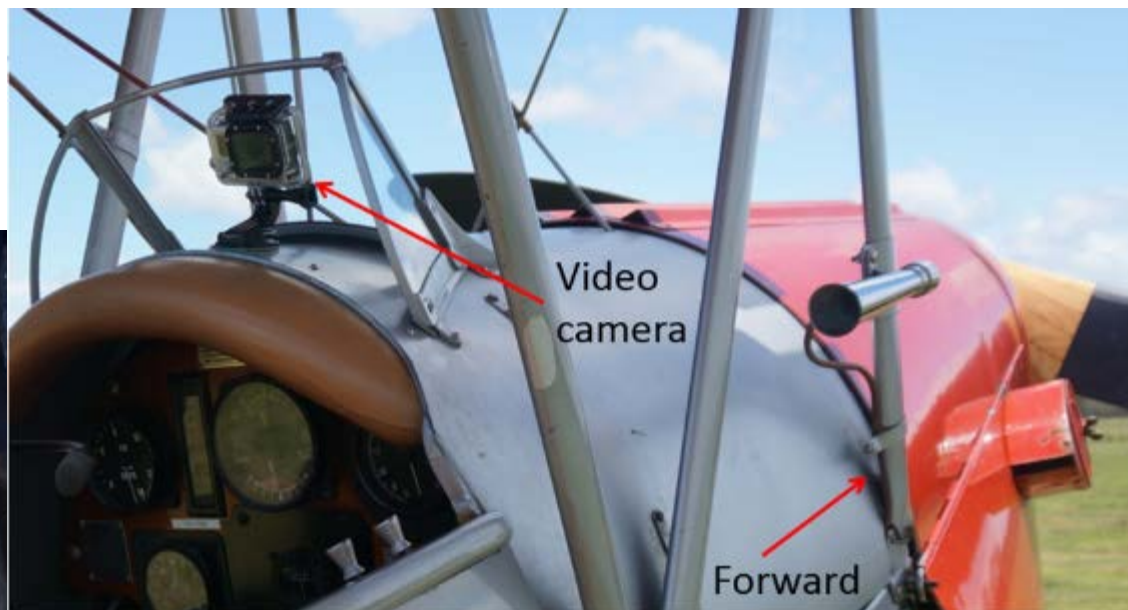
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Wing attachment points



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Video recording device



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First three frames



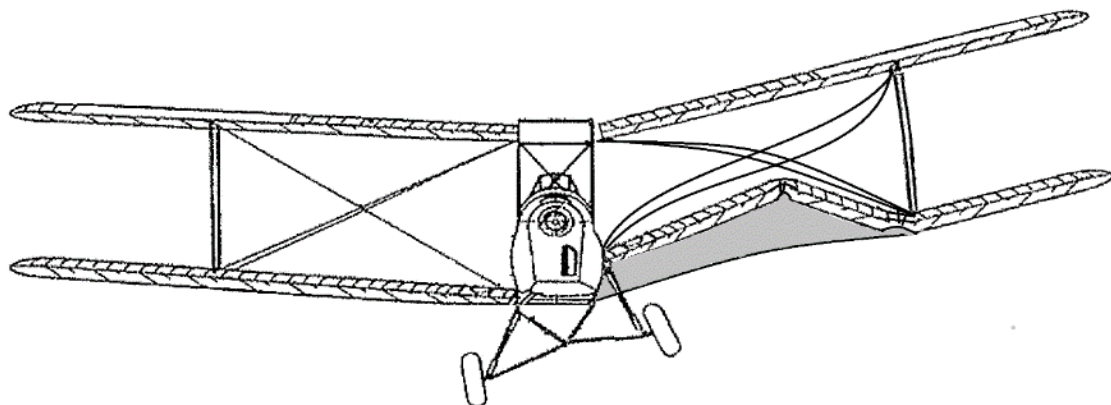
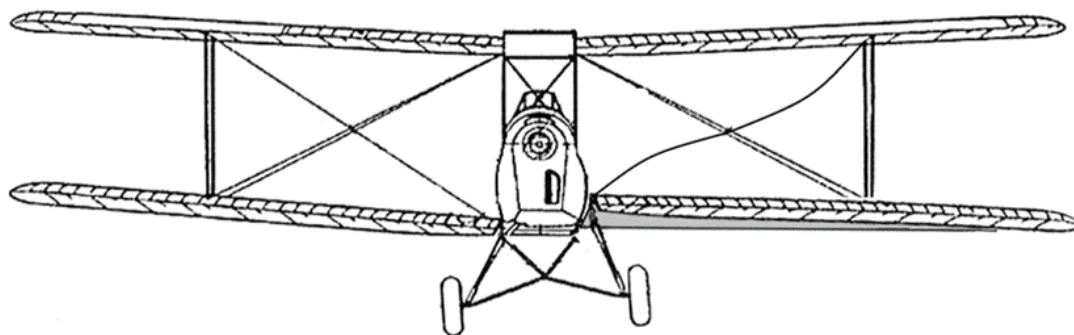
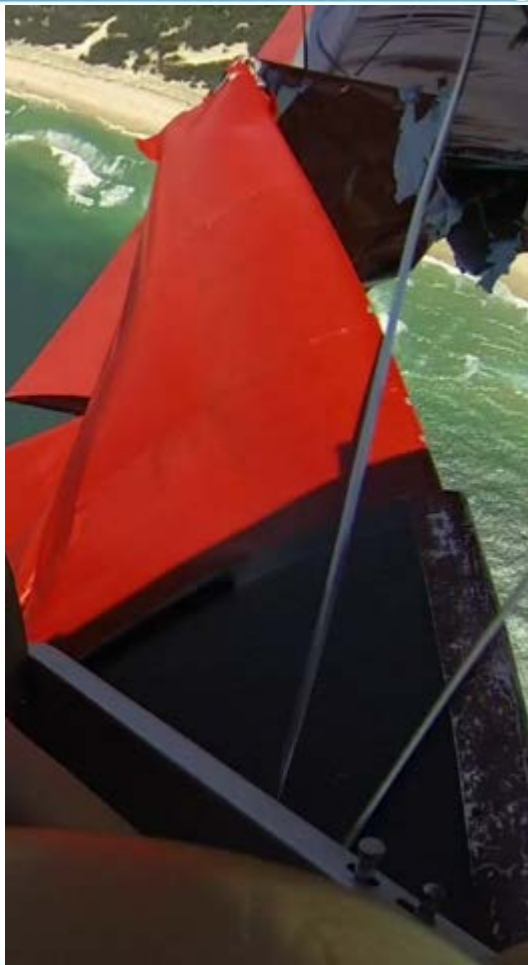
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Flying wires come into view



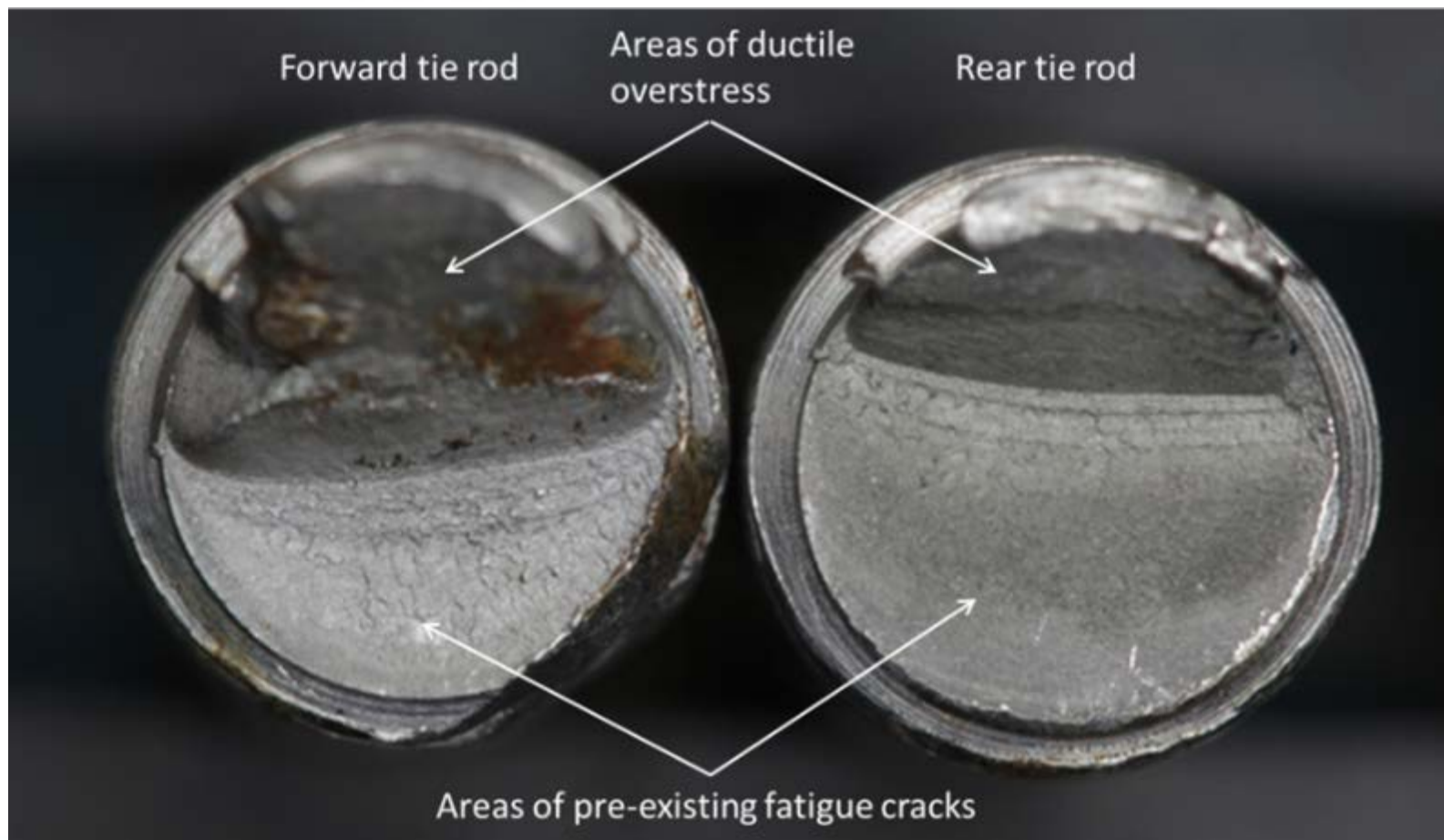
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Total wing failure



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Lab inspection of retained parts



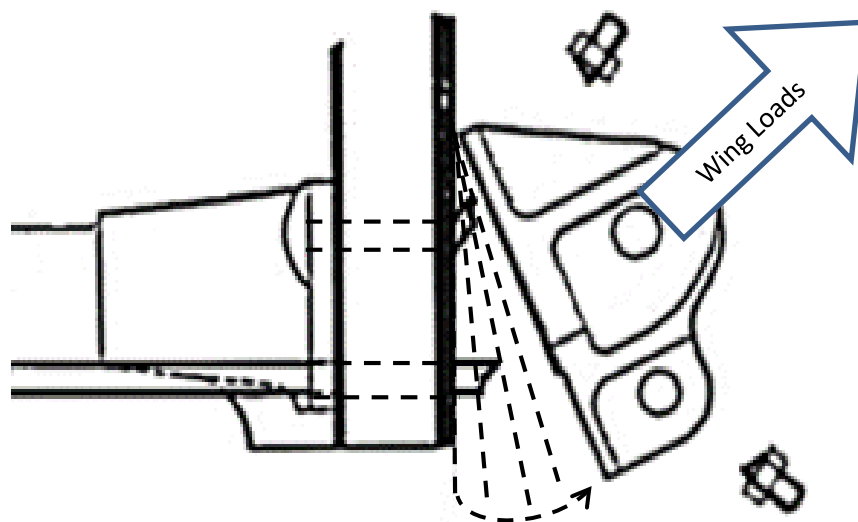
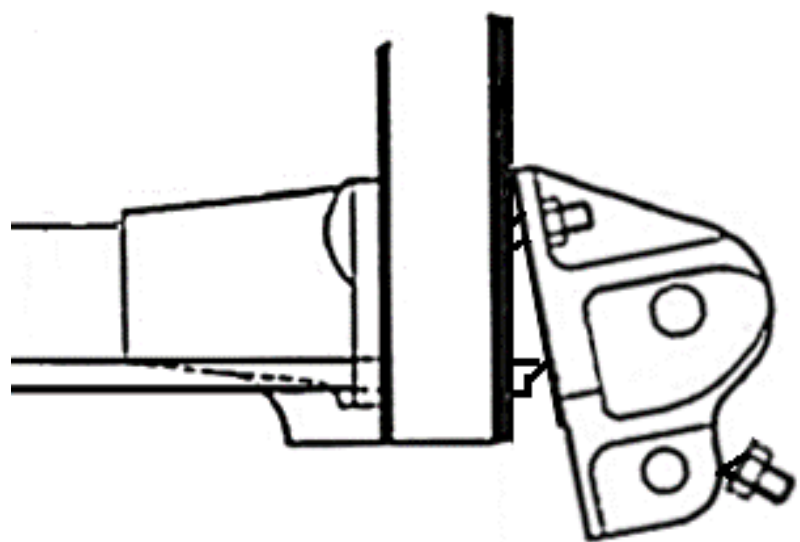
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Right side forward tie rod



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Initiation point of wing failure



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What is fatigue?

Metal fatigue is the progressive and localised structural damage that occurs when material is subjected to cyclic loading

It is influenced by a number of factors, including:

- Fatigue strength of the material
- Surface finish of the material (notch sensitivity)
- The fatigue loading (direction and force applied)
- The amount of cycles

Tie rod metal fatigue history

In 1996 a routine Tiger Moth maintenance inspection identified one tie rod end which had fractured at the thread root due to metal fatigue. The other tie rod also had fatigue cracks in both ends but had not yet progressed to complete failure. The tie rods had about 4,200 flight hours in service

The aircraft type approval holder introduced a tie rod retirement life of 2000 flight hours or 18 years for all Tiger Moth tie rods.

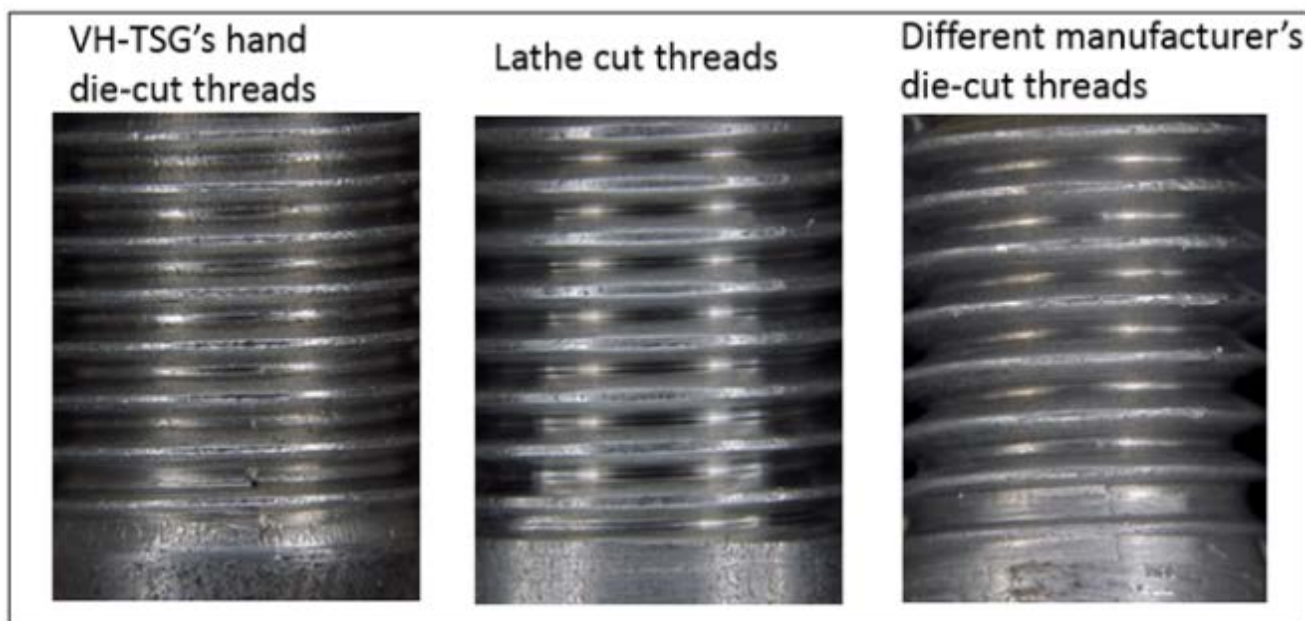
That retirement life was mandated by a UK airworthiness directive which was also duplicated by CASA.

VH-TSG tie rod history

- The tie rods were about seven years and 1,300 flight hours old, which was within the stipulated fatigue life expiry of the part.
- Made in Australia under an Australian Part Manufacturing Approval.
- Original design changed with the substitution of carbon steel with 431 stainless steel.
- Material was the same strength as the original design but the materials fatigue resistance was unknown and unsubstantiated.

Surface finish

- VH-TSG's tie rods had a rough surface finish when compared to other tie rods from the same manufacturer and others.
- Rough finish appeared to be due to the method utilised to form the thread (hand die cut). As opposed to lathe cut and Coventry die cut.



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Aerobatic usage

- Aerobatics usage increases fatigue cycles and flight loads imparted on the aircraft structure.
- The Tiger Moth is rated as a semi- aerobatic aircraft with limitations on type of aerobatics but not the amount.
- Designed as an elementary training aircraft, originally for the military.
- Design assumption was for the cumulative effect of high aerobatic loading to be diluted by greater use on tasks such as cross country navigation and circuit training.
- VH-TSG was used for commercial joy flight operations involving a significant amount of aerobatics on almost every flight, which was far and above the original design assumptions.

Upper attachment bolts



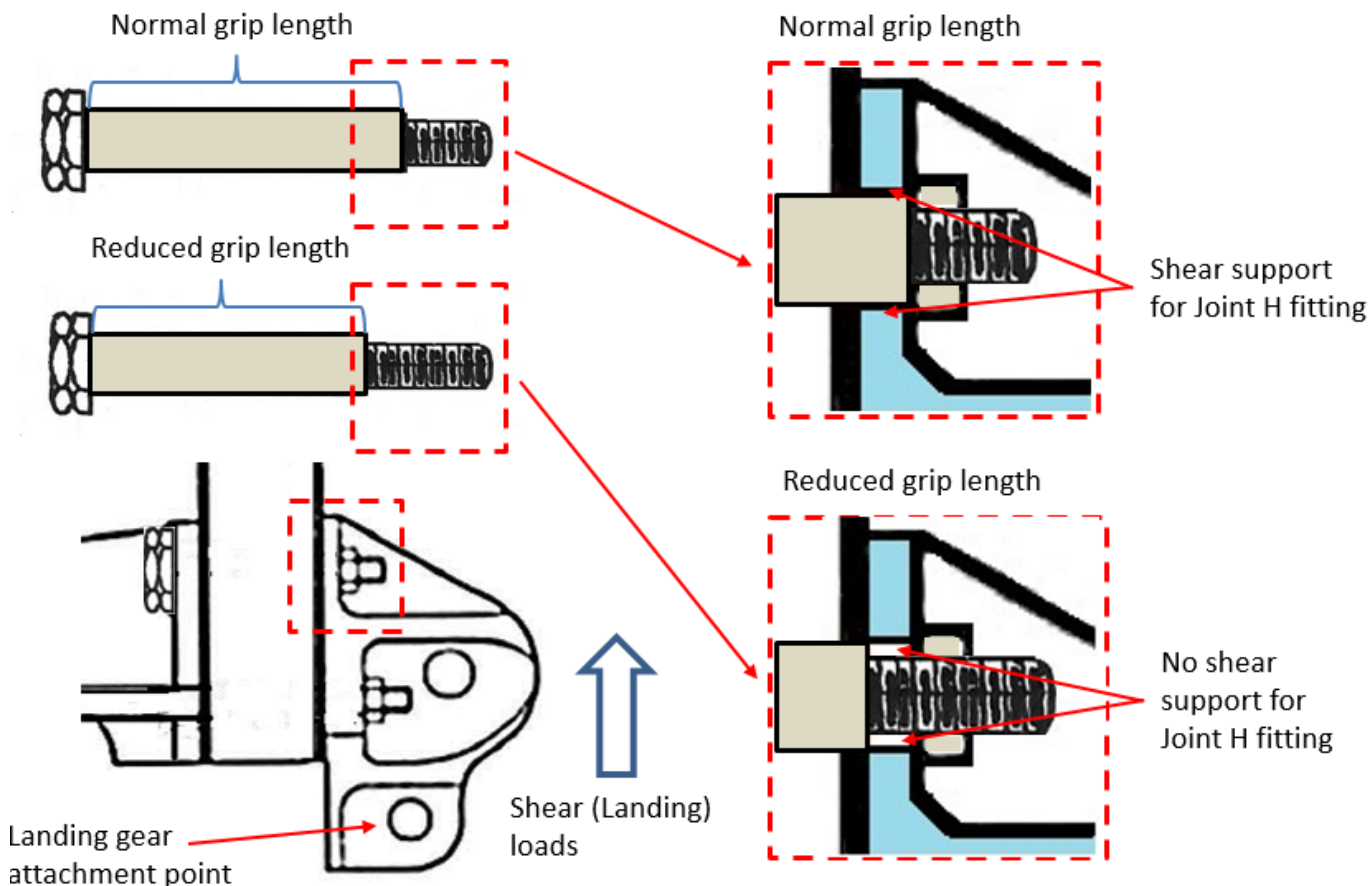
The upper attachment hardware was a close tolerance bolt specifically designed for Joint H.

VH-TSG had non-standard parts of unknown origin.

Two of the three retained Joint H upper attachment bolts had a shorter than normal grip length



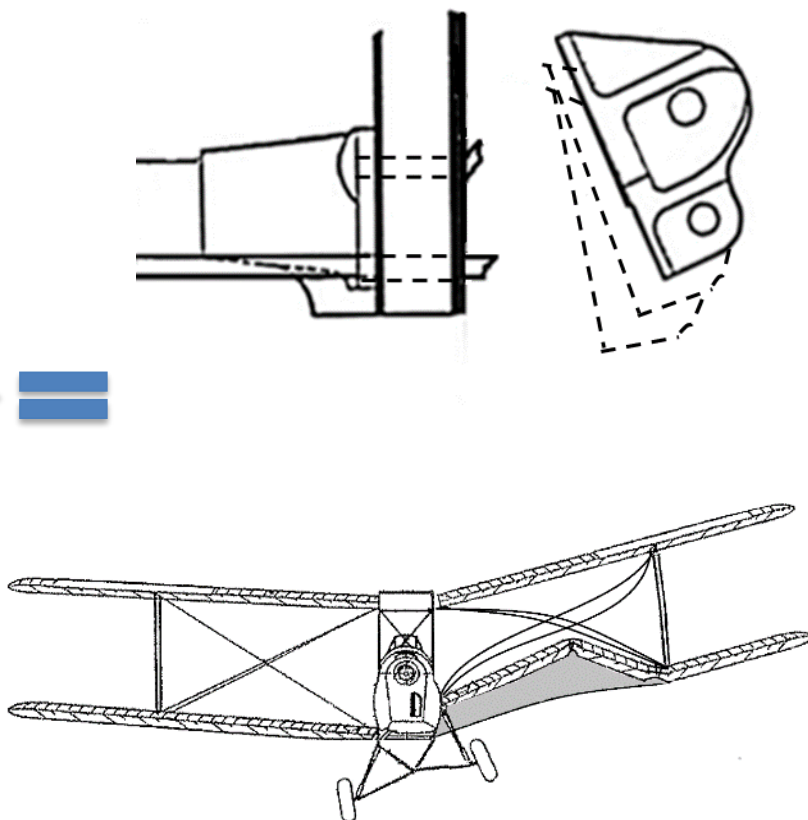
Additional loads



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Contributing factors

Material substitution ?
Rough cut threads
High aerobatic usage
Incorrect attachment bolts



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Tie rod design

- Australian aircraft parts manufacturer requested a design for replacement Tiger Moth tie rods in 1998 from a design engineer.
- Australian design engineer copied design from the manufacturers specification, but changed the material used to an aviation grade stainless steel of equivalent strength.
- Engineer did not research the original part to see if there were life limitations imposed, or if the part was subject to service difficulties or fatigue issues.
- Tie rods were subject to fatigue life expiry, a technical news sheet and an airworthiness directive. That being the case, the design engineer should also have considered fatigue strength equivalence in his design justification when material was substituted.

APMA approvals

- Australian parts manufacturing approvals (APMA) were introduced by CASA in 2000 as an aircraft part design and manufacture standard
- All aircraft parts manufacturers had to show compliance with the APMA standards and guidelines before they were allowed to mass produce aircraft parts for sale (excluding one off replacement parts)
- A dead line of November 2003 was given in order for all parts manufacturers to submit applications for APMA manufacturing and design approvals of previously CAR 35 approved parts
- The tie rod manufacturer submitted over one thousand designs for CASA APMA approvals, including the tie rod design
- Due to the time it took for CASA to approve APMA's through its normal process the manufacturer made numerous complaints to senior CASA staff and also local and federal ministers.

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APMA approvals

- Due to the delays and complaints, CASA formed the regulatory reform programme implementation (RRPI) team at the end of 2002
- The CASA director issued a policy notice to the implementation team which stated that they were allowed to take the design engineer (CAR 35) approvals on face value
- That policy allowed the rapid approval of over 1100 aircraft part designs within the stipulated timeline of November 2003, without following the rigorous CASA APMA approval guidelines
- The CASA APMA guidelines showed a requirement for aircraft part designs to consider service difficulties, items with fatigue life expiry and items subject to airworthiness directives.

APMA approvals

- Had CASA followed its own approval guidelines, it would have identified that the original tie rods fitted to Tiger Moth aircraft were susceptible to fatigue, were the subject of a CASA airworthiness directive, service bulletin and fatigue expiry life.
- Under their own guidelines they would have requested that the design engineer conduct a fatigue justification for the material substitution.
- The ATSB considered this and the approval of the other 1100 aircraft parts to be a safety issue which required rectification
- CASA was issued with a safety advisory notice and briefed by the team in person
- A satisfactory response to the issue was not forthcoming, therefore the ATSB issued a recommendation for CASA to address the issue.

Safety issues

- Seven safety issues were identified during the investigation
- Four were resolved due to closure of the manufacturer and design engineer businesses
- Two involved the CASA parts approval of the tie rods and other APMA approved parts (recommendation issued)
- One involved the amount of aerobatics that could be conducted in the aircraft.

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Safety actions

- Worldwide AD for the removal of J & R tie rods
- CASA AD mandated the requirements of TNS 32 timber structure inspection
- UK CAA AD pending on Tiger Moth aerobatic flight limitations
- UK CAA AD and TNS update pending for reduction in tie rod expiry based on the amount of aerobatics conducted
- UK CAA AD pending for upper attachment bolt inspections for original parts
- CASA response to ATSB recommendation received and being assessed by the ATSB.



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Thanks! Questions?

Learn from the mistakes of others. You won't live long enough to make all of them yourself.



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